duced the motion, that he had in mind the ordinary member of the public, and particularly the child in the elementary school, and appeared to be under the impression that the expert was already sufficiently well cared for. An instructive feature of the debate is the almost entire absence of any reference to science in general, or to the Natural History Museum in particular. Another revealing point is suggested by a passage in Lord Crawford's reply for the Government, in which, in reference to Lord Bryce's proposal that a central scientific department of the Government should be set up, he said: "Among the purposes for which the Scientific and Industrial Research Department was set up . . . is actually that of acting as a central advisory body on any scientific question in relation to any Government Department"; for, apropos of this statement, we must observe that, whereas every administrative Department is represented by at least one assessor to the Advisory Council, that Department appears to be unaware of the existence of the Natural History Museum. Lord Sudeley's motion was eventually by leave withdrawn; nevertheless, we hope that the matter will not be allowed to rest there. We think, indeed, the question of sufficient importance for the consideration of a Royal Commission, the terms of reference of which should include the system of remunerating the specialist, who at present enjoys a much lower scale of salary than the administrator of corresponding standing, and we strongly urge the Government to appoint one with the least possible delay.

Mathematical Cosmogony.

Problems of Cosmogony and Stellar Dynamics. By J. H. Jeans. Being an essay to which the Adams prize of the University of Cambridge for the year 1917 was adjudged. Pp. viii+293+v plates. (Cambridge: At the University Press, 1919.) Price 21*s*. net.

IN a well-developed science two branches are broadly to be distinguished. In the one, an existing state of things is investigated. The subject of research is events immediately connected, forms, functions, and the laws which govern them. The other branch generally marks a later stage, and, basing itself on the results of the first, seeks to reconstruct from the present as complete a picture as possible of the past and even of the future. As in the conception which underlies the theory of relativity, the present, which is the limited subject of experience, is merely a section in time from which a higher manifold is to be deduced. When the subject-matter is biological, the outcome is a theory of evolution. When it coincides with the domain of astronomy, the result is more specifically recognised as a scheme of cosmogony.

There are at least three methods by which attempts have been made to formulate such a scheme. The first, and most trivial, is to seize on some remarkable phenomenon, like Saturn's rings or a spiral nebula, and to see in it a clue which can be followed up more or less plausibly with the help of an exuberant and unfettered imagination. Progress on that line is naturally as limited as it is precarious. The second method is illustrated in its highest form by the work of Sir W. Herschel. It is the way of comparison and classification. The Draper classification of stellar spectra by Pickering is an apt modern example. Without preconception, except such as readily vanished in the light of fuller experience, almost all the stars fell into an ordered sequence, which became more complete and continuous as the material accumulated. To connect the ascertained sequence with a time scale was natural. But the problem has not proved quite so simple as at one time it appeared. In general, when the process is exceedingly slow and the section of experience correspondingly thin, the very direction of the scale is ambiguous, and the method requires to be supplemented by some additional principle. A third method remains. This consists in the study of models having a definite specification as nearly as possible in accordance with cosmic examples, but always within the power of analysis to discuss. The behaviour and development of such a model are traced to their logical consequences with full mathematical rigour, and only after this has been done is an attempt made to find their counterparts in the actual universe. This is the profoundly difficult but promising method adopted by Sir George Darwin, by Poincaré, and by Mr. Jeans in the work under notice.

It is curious how great are the difficulties which surround problems capable of the simplest statement. Three balls are thrown in any given way in empty space. All the intractable difficulties of the problem of three bodies are involved in discussing the subsequent motion under their mutual attractions. Or again, to take the fundamental problem of the present subject, a mass of liquid is stirred into rotation and left to find its shape under its own attraction. What figure will it assume when isolated in space? The following quotation from Thomson and Tait may be worth recalling:—

"During the fifteen years which have passed since the publication of our first edition, we have never abandoned the problem of the equilibrium

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of a finite mass of rotating incompressible fluid. Year after year, questions of the multiplicity of possible figures of equilibrium have been almost incessantly before us, and yet it is only now, under the compulsion of finishing this second edition of the second part of our first volume, with hope for a second volume abandoned, that we have succeeded in finding anything approaching to full light on the subject."

The full light, it must be admitted, was rather dim, especially as such results as had been obtained were published without proof. But it sufficed to lead Poincaré to write a celebrated memoir on the subject, and this, with the contemporary and independent work of Liapounoff, has been the germ of all subsequent advance.

The first step had been taken by Maclaurin, who showed that the spheroid was a possible figure of equilibrium. The second solution was found by Jacobi in the form of an ellipsoid with three unequal axes. In the cosmical problem the whole mass and the moment of momentum are given constants; the angular velocity increases as the state of contraction advances, but so slowly that the development follows a succession of equilibrium figures. Thus a body traces out the series of Maclaurin to the point where it meets the series of Jacobi, and where secular stability is interchanged between the two series. Proceeding along the second series, it comes to the first point, discovered by Poincaré, where another possible series intersects. Here the Jacobian series becomes unstable, and it was a question whether the stability passed over to the series of deformations, or whether it disappeared completely at this point, in which case the figures of statical equilibrium would come to an abrupt end and be followed by a rapid change under dynamical conditions.

It was not in Poincaré's nature to embark on the complicated arithmetic needed to solve the question; but this part of the work was supplied by Liapounoff and by Darwin, who arrived at opposite conclusions, the latter maintaining that the deformed figure was stable. These three writers all used Lamé's functions in the discussion, and carried the development to the second order. One cannot help feeling that, in spite of his courage, Darwin was in this instance trying to stretch a bow a little beyond his strength. At any rate, the important problem remained undecided for some years. Mr. Jeans began his attack on it by forging a lighter and handier weapon, described in chap. iv. of the present work, on the gravitational potential of a distorted ellipsoid. His next step was to show that no conclusion could legitimately be drawn from a development to the second order; and finally, on proceeding to the third order, he proved definitely that the figure at the point where the series bifurcate is unstable, thus closing a dispute remarkable in the case of a definite issue between authorities so eminently qualified. After this signal achievement as regards the incompressible fluid mass Mr. Jeans extended his researches to rotating masses of compressible and heterogeneous fluid, hitherto an almost untouched field. In following out the development of such bodies as exemplified in different selected models, he has shown always the same originality, resource and power.

In the present essay, which will be warmly welcomed, Mr. Jeans brings together these and other related researches in a connected form, but at the same time he adds so much of the work of his predecessors that his own is seen in its proper setting, and the whole book forms a fairly complete treatise on the subject. The earlier chapters provide that firm mathematical foundation to which the author has contributed so largely, while the later chapters deal in turn with the different classes of celestial objects to which the theory can be applied—rotating nebulæ, star clusters, binary and multiple stars. The origin of the solar system, the very point at which speculations of this order began, remains apparently more elusive than ever. The later part of the book can be read with profit by many to whom the power of appreciating the earlier mathematical chapters has been denied. It will be found exceedingly interesting, and will repay the most careful attention. Here the speculative element necessarily enters, and the permanent value which belongs to the abstract problems definitely solved cannot be assumed. But ingenuity and a wide knowledge are always in evidence, and the essay should have an immediate value equally in limiting the area of profitable speculation and in suggesting lines which can be controlled by observation.

Of the technical excellence of the production, which is always a point of real importance in a mathematical text, it is unnecessary to say more than that it is worthy of the Cambridge University Press. There is an obvious, and therefore harmless, misprint in equation (72) (p. 38), and "Meyers" (p. 248) for "Myers" betrays an unverified quotation. On p. 2, "parallaxes are less" should read "greater." But these are trifling exceptions to the rule of accuracy. Beautiful pictures like the photographs of selected nebulæ included by Mr. Jeans are an unusual feature in a mathematical work. They have been supplied from the Mount Wilson Observatory, and are masterpieces of their kind.

H. C. P.

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